EMOTIONALLY EVOCATIVE ENVIRONMENTS FOR TRAINING

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ABSTRACT

This paper describes a project currently in progress at the University of Southern California's Institute for Creative Technologies (ICT). Much of the research at ICT involves developing better graphics, sound and artificial intelligence to be used in creating the next generation of training tools for the United States Army. Our project focuses on the use of emotional responses as an enhancement for training.

Research indicates that an emotional connection is a strong factor in how and what we remember. In addition, real world situations often evoke surprising and significant emotional reactions that soldiers must deal with. Few current immersive training scenarios, however, focus on the emotional state of the trainee, limiting training scenarios to basic objective elements. The Sensory Environments Evaluation (SEE) Project at ICT is investigating the potential of emotionally compelling environments for more effective training. We do this by skillfully combining the sensory inputs available in virtual environments. Our current efforts concentrate on sight and sound; smell will be included as scent delivery methods improve. Evaluation studies are planned to determine the effectiveness of the techniques we are developing.[+]

Keywords: Immersive Training Environments, Virtual Environments, Virtual Reality; Emotional Architectures.

1. MOTIVATION

A key issue associated with many training environments is their believability, since this quality is generally considered to heighten the effectiveness of the training situation. In addition, retention of lessons learned is a serious concern, as a soldier who does not retain what he or she has learned has not been successfully trained.

To date most immersive training environments have concentrated on either visual realism or physics-based accuracy, or both. However, these techniques require significant computer processing power to achieve. Compromises are typically necessary and often result in a less effective system. We contend that by using skillful combinations of sensory inputs designed to trigger emotional responses, we can achieve a "feels real" rather that a photo-real or physically-real training system. Research has shown that emotionally charged situations are remembered longer than emotionally neutral ones. [See for example McGaugh, 2002, and Ulate, 2002] It is our belief that an emotional connection also helps provide an increase in the classic "suspension of disbelief" reaction, thus bringing the trainee more in synch with the simulation. If this is true, it has two potential positive effects for training. The first has implications for better retention, since emotionally charged situations tend to form longer-lasting memories. The second is that today's recruits often need better skills to deal with highly charged emotional situations that they may find themselves in, given the changing face of modern conflict. More emotionally rich training environments may provide a means to help them gain valuable emotion-coping skills, in addition to more accurate recall of these and other lessons.

2. THE DARKCON SCENARIO

2.1. Description

Our first emotional-based scenario, entitled "DarkCon", places a participant in the role of a long-range reconnaissance patrol in war torn Bosnia. The setting is at night, and the scout is dropped into a remote location and instructed to get in extremely close to a suspected rebel hideout. He is to surveil and report on enemy activity in an abandoned mill complex along the Banja Luka River. He is also to be on the lookout for certain items that have recently been found missing from a cantonment area. He will be required to give a full report for his AAR.

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The area has certain dangers associated with it: landmines along the secondary roads, a village in close proximity, evidence of refugees being held and possibly killed, and few places to hide.

Using techniques derived from both computer science and entertainment technology, we have created a visual and auditory immersive environment based around this scenario that is exceptionally rich and dynamic, containing both intense and subtle triggers that affect emotional engagement.

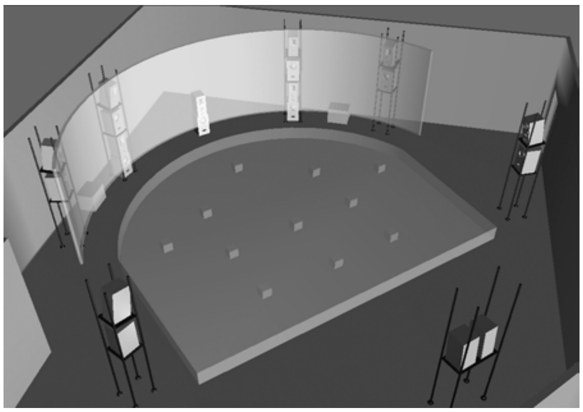

Figure 1. Schematic of ICT's VR Theater showing the curved screen and the 10.2 sound system and "rumble floor."

2.2. Technical Setup

DarkCon is a full three-dimensional virtual world that consists of an approximately one kilometer square database representing a typical Eastern European terrain. The models are displayed via custom Performer-based code running on a Silicon Graphics Reality Monster. Three pipes are used to display the real time graphics signals via three Barco CRT projectors, blended across a 150° curved screen at ICT's facilities in Marina del Rey. [Figure 1] The theater visuals serve primarily to involve an audience in what the "trainee" (played by a member of the SEE Team for demonstration purposes) would see during the simulation. The "trainee" wears an HMD for first-person immersion [Figure 2] and sees a 50° FOV, which corresponds to the center screen image the audience sees. Stereo is not implemented at this time but two channels could be easily sent to the HMD. Navigation is accomplished through a joystick that permits forward, backward and side step motion. Tracking in the virtual space is done via an acoustic and inertial system from InterSense and provides the vertical movement as well as orientation for the trainee.

3. METHODOLOGY

3.1. Design Philosophy

We strive to create environments with a high level of believability. However, our aim is not to make them just photo-real, but rather to provide a compelling world with a high degree of presence that "feels real." By using clever technical and artistic tactics, some borrowed from the Hollywood film industries, we are able to compensate for the inherent constraints of rendering in real-time. This is especially true in the integration of multi-sensory cues, which in combination can synergistically achieve believability, where individually the same cues could not. Special thought is given to combinations of sensory information that can build upon each other.

Figure 2. Trainee in HMD. 150 degree screen is seen by onlookers.

Larry Tuch, a Hollywood writer whose credits include film, televison and location-based entertainment, wrote the script for DarkCon, and worked closely with us to incorporate our design principles. In addition, to contribute to the realism, he consulted with key subject matter experts who had been to Bosnia and on such missions.

To make the environment come alive we borrow techniques from Disney animators. As they began to perfect their art, they realized that one should never freeze a character in a scene, even if that character was not talking or moving, or the scene would lose its liveliness. This went against the conventional practice of the time where only characters involved in some action would be drawn, thus speeding up the production cycle. Disney's cartoons may have taken longer to create, but they had an unrivaled life-like quality. We believe this philosophy holds true for virtual environments. Characters should never stand absolutely still and neither should other objects in the world. Anything that moves in the real world should move in the virtual world, even if the movement is subtle and slight. For example, the trees on

the opposite bank could move slightly in the wind. The bridge should creak and sway when the heavy trucks traverse it. A grating may clank slightly if a tire rolls over it. A rock or stone may fall off the tunnel wall from the vibration. The moon should rise slightly in the sky and the clouds should be driven across the front of the star field as if there was a breeze blowing. Characters, especially, should always exhibit some slight, realistic movement, even when at rest.

This liveliness also applies to the auditory aspects of the environment. Sound design is equally important as the graphics for SEE, perhaps more so in our dimly lit environment. Just as it is never truly quiet in the real world, the virtual one should have this same quality. Therefore we pay as much attention to incorporating subtle sounds as we do the loud or important ones, and there is never a totally silent moment. Ambient sounds that make sense are used wherever possible, such as the trickle of water in the culvert, distant sounds of the river, occasional debris falling when a truck passes, dogs barking and distant trains. These all serve to increase the believability and feeling of presence. Many of these sounds may not even be consciously noted in the simulation, but if they were absent, the environment would feel less realistic and engaging.

Real time sound spatialization is another key element that contributes to believability. This technique is used for such elements as passing vehicles, certain creature sounds, and overheard voices or radios. Knowing the direction from which a sound emanates is a critical observational skill and therefore a key component of our scenario design.

A final element of our sound research involves the use of more visceral low frequency sounds to augment the participant's emotional state. These sounds may actually be below the threshold of hearing, but still can have impact. We use these non-auditory signals much like a film utilizes a musical score (which would be very out of place in a virtual world). We can map out the expected emotional "score" of the VR experience using techniques such as frequency modulations, syncopations (e. g. an increasing heartbeat rhythm) and spatial movement of the frequencies (such as emanating from a perceived source of danger and traveling towards the participant). This visceral sound is achieved through a custom-built floor that contains a grid of ten addressable low frequency transducers. The trainee stands on this floor during the experience.

Along with the graphics and sound techniques, we are also concerned with how we enable the trainee to build a narrative sense of the training scenario. We use visual, auditory or design cues to lead the participant along the most informative path through the experience. We refer to these cues as "Coercive Narrative" elements. It includes aspects that both attract (e.g. a flashing light accompanied by a loud rhythmic noise) and detract (e.g. sounds of voices within the building). We also try to incorporate standard military protocol within this framework, which helps proscribe certain actions. We also take into account the actual mission instructions given to the trainee. [Morie, 2002]

All these design elements combine to culminate in the final experience. The resulting DarkCon Scenario, with its detailed graphics, full environmental, directional and visceral sounds, and coercive components, presents an extremely compelling experience, even in its initial stages.

3.2. Simulation

The simulation currently consists of a collection of "simulation atoms", which are small units of work that generate signals and data. On each time step of the simulation, an atom does some work, handles any signals it has received, and then generates signals to be handled by other atoms. A timer atom, for example, would delay propagation of signals until the specified time has elapsed. Likewise, a region trigger atom would generate a signal only when another atom enters the specified region. By specifying relationships and signal routes between atoms, we can construct networks of atoms that embody scenario concepts. This allows us to reuse pre-built networks in high-level simulation descriptions.

Our current representation of routing is a directed acyclic graph, or tree. An atom only sends signals to atoms that are downstream in the tree. This representation simplifies the handling of signal and data propagation, while still providing adequate expressive power to the scenario designer. For instance, a "vehicle" network, for use in simulating cars and trucks [Figure 3], is built using a physics atom, a geometry atom, and a sound atom. The physics atom controls basic physical parameters, such as position and velocity. The geometry atom controls communication with the rendering system, geometry loading, and animation, and the sound atom controls sonic parameters and communicates with the sound system. By routing signals into this "vehicle" network, we can build larger networks that control the "vehicle" in various ways. One such tree might have a "vehicle" start moving when a user moves through a specified region. [Figure 4]

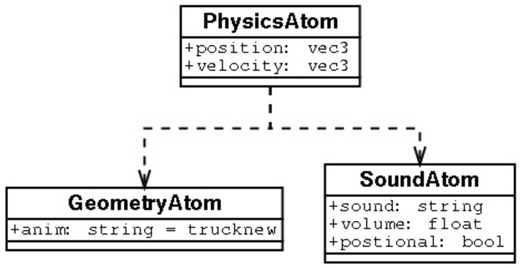

Figure 3: Vehicle network

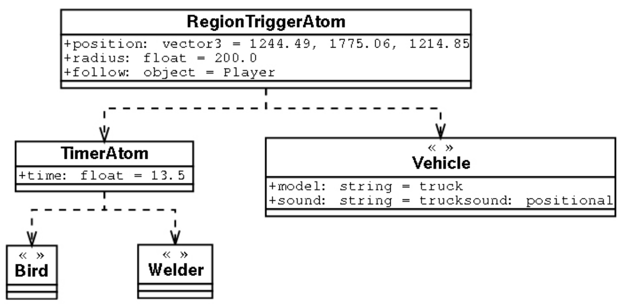

Figure 4: Sample simulation node

3.3. Visuals

We use many techniques in the pursuit of our "feels real" environment. Early in the design process we thoroughly research real world analogs of the environment we're trying to mimic. We look closely at references found on the web, in image libraries and on film, and in the best case, visit actual locations.

Corroborative details define the essence of an environment. We pay close attention to objects that create such detail – things that may evoke memories or tell a story. Such details use much of our polygon budget. In addition, we optimize our models by incorporating blended Level of Detail models. This method seamlessly switches out detailed objects with their low-resolution stand-ins as they move away from view. We compensate for the faceted look of low-polygon models by applying layers of photo-realistic textures with built-in transparency. Painting rust onto the pipes and grime on the culvert walls, much like set decoration in films, adds to the richness of the simulation.

Lighting is a challenge in this mostly dark scenario illuminated primarily by moonlight. Even accurate global-illumination lighting-models would not work in this case, since the interior culvert would be too dark for the participant to navigate through. But in films we are always able to somehow "see" in the dark. In a similar fashion we use a number of tricks to be able to provide adequate lighting while preserving the illusion of night. These lighting techniques include vertex lighting, hardware lighting and simulated reflections.

Figure 5: Looking across the river. Lit with vertex lighting.

Most of the scene [Figure 5] is bathed in a static moonlight using vertex lighting. Using this method of painting the light onto the models at the vertex level allows for faster processing. But in Figure 6, the vehicle and its immediate area are being light by a hardware light that is synchronized to a welder's (working in the fenced in yard) grinding action and sound.

Ray-traced reflections are prohibitive for real-time renders. But in the muddy water of the culvert we were able to simulate limited reflections by selectively mirroring the geometry. A thick atmosphere adds a lot to our believability objective, pushing objects in the distance even further back and helping us avoid the look of a typically clean VR world. These are just a few ways we optimize our computer models to create convincing virtual environments.

Figure 6: Hardware lighting on the welder and vehicle in the yard. Note the fog in this image and above in Fig. 5.

3.4. Sound

3.4.1. 10.2 Sound System

Scenario DarkCon utilizes a proprietary "10.2" spatialized sound system which was developed by Dr. Chris Kyriakakis at USC's Integrated Media Systems Center. Unlike traditional virtual environments that require head phones to provide spatialized sounds, this system is room-based and requires no special headgear. The additional channels beyond the standard 5.1 sound systems bring a full hemisphere of sound to the participant. Special algorithms allow for three-dimensional tracking of triggered audio elements. Our newest software addition to this system is a method for on the fly spatializing of multiple concurrent sounds.

3.4.2. Maestro Sound Engine

The SEE Project is creating a robust set of sound development and pipeline tools collectively referred to as the Maestro Sound Engine. These tools include ways for the modelers to link distinct sounds or sound textures to their related objects, or even create invisible sound objects, by means of plug-ins to the modeling software. Once the models and their associated data are in the simulation, the audio components are relayed via Ethernet to the audio software. This software directs a custom software sampler that buffers the sound clips and plays them at the appropriate time. The heart of the system is the Multichannel Panner. This dynamically pans or moves sound elements in three-dimensional space. We also plan to add a sophisticated acoustic simulator to model the reflective or absorptive properties of the graphical environment.

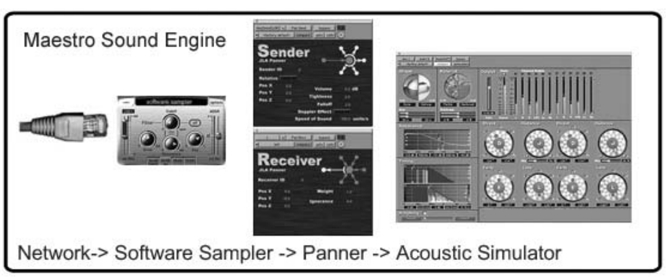

Figure 7. Basic Maestro Sound System

3.4.3. Rumble Floor

The so-called "Rumble Floor" is a specially constructed floor approximately ten by twelve feet containing an irregular grid of ten low frequency transducers. These are under Maestro control and can be used in two ways. First, they can be played at a high intensity to shake the audience, as when a truck rumbles by, or an explosion occurs. This provides a tactile quality to the simulation without the use of haptics. They can also be addressed individual or as a group in more subtle ways to provide the emotional "score" described earlier.

4. EARLY RESPONSES

We are in year two of our development for the Sensory Environments Evaluation Project. Preliminary responses have been very positive, with early test participants reporting robust engagement with the immersive space, including feelings of fear, urgency, disquiet and heightened awareness. Two of our most interesting subjects were summer interns from West Point. One of the cadets went through the training mission exactly as we expected. The other ran into technical problems with the collision detection system and was not able to complete his mission. Both were able to provide suggestions for improvement, based on what they felt worked or was lacking in the environment. This type of feedback is invaluable for us to iteratively improve the quality of our design and interaction, building towards a scenario robust enough to be used for the final evaluation studies.

5. FUTURE ENHANCEMENTS

Future work will expand the scope of the DarkCon Scenario by adding three-dimensional characters, whose motions are animated or derived from motion capture. These characters will have a library of actions that can be blended in various ways, either through a random sequence when they are not engaged with the trainee, or by specific behaviors that indicate interaction or consequence.

Smell is a sensory device that is rarely used in virtual training environments. However, it should not be overlooked for training as it provokes strong emotional connections and can provide increased richness to the scenario. As the most evocative of our senses, smell can be used to contrast or heighten a particular emotional effect. Smells can either correspond or contrast to the scene being viewed (e.g. good smell to good visual or bad smell to good visual). Our sense of smell differs from sight and sound in two important ways. First of all, we smell by means of an actual intake of molecules with which our body interacts. Thus it is a chemical sense (as is taste). Secondly, smell is first processed by the emotional parts of the brain, and is rationally analyzed only after some delay. [Pine, 1995] Both these aspects have implications for smell's use within training environments.

We are currently designing a custom, lightweight scent delivery device that can be comfortably worn by a trainee, and are actively looking for partners to aid in its fabrication. We recognize that smell is probably the least

explored and understood design challenge we face and therefore promises to offer rich new veins of research in regards to its power to augment the emotional experience.

6. EVALUATION STUDIES

The core of our investigations is based on a robust testing phase to determine the effectiveness of our techniques. These final evaluation studies will collect information from a range of test subjects. Data will include pre- and post-experience questionnaires and actual physiological data (heart rate, galvanic skin response, and other non-invasive real time tests) obtained from subjects during the experience. We plan to use a wireless device called the Bio-Radio from Cleveland Medical Devices for the physiological monitoring. The questionnaires will be derived from Witmer and Singer's Presence Questionnaire (PQ) and Immersive Tendencies Questionnaire (ITQ). [Witmer and Singer, 1998] Results from the evaluation studies will be reported, correlated, analyzed and published.

7. CONCLUSIONS

Putting this attention on the emotional state of the trainee allows us to design training scenarios form a new and intriguing perspective. We hope our efforts will lay the groundwork for a scientific understanding of how to predictably generate emotional connections in immersive training scenarios thus increasing their effectiveness for the future soldier.

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